

Lemon Rootstock Trials in Arizona – 2003-04¹

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Abstract

In a rootstock evaluation trial planted in 1993, five rootstocks, 'Carrizo' citrange, Citrus macrophylla, 'Rough Lemon', Swingle citrumelo and Citrus volkameriana were selected for evaluation using 'Limoneira 8A Lisbon' as the scion. 1994-2003 yield and packout results indicate that trees on C. macrophylla, C. volkameriana and 'Rough Lemon' are superior to those on other rootstocks in both growth and yield. C. macrophylla is outperforming C. volkameriana. For the second year in a row, 'Rough Lemon' trees performed similarly to C. macrophylla and better than C. volkameriana. 'Swingle' and 'Carrizo' are performing poorly. In two other rootstock evaluation trials, both planted in 1995, C. macrophylla and/or C. volkameriana are outperforming other trifoliate and trifoliate-hybrid rootstocks under test.

Introduction

There is no disputing the importance of citrus rootstocks to desert citrus production. The ideal citrus rootstock must be compatible with the scion, be adaptable to the appropriate soil and climactic factors and should also improve one or more of the following characteristics: pest and disease resistance, cold tolerance, precocity, internal and external fruit quality, yield and/or post-harvest quality. Ultimately, the value of a rootstock lies in its ability to improve production and/or quality of the fruit.

Climactic and edaphic characteristics of the desert citrus growing regions impose stress upon a citrus tree. Many times, rootstocks that are suitable for other areas are not suitable in the desert. Conversely, rootstocks that may be of limited value in other citrus growing areas might be more useful under desert conditions. It cannot be assumed that rootstocks will perform similarly across all climactic and edaphic conditions.

The first rootstock trial that we planted in 1993 was established to fill a large knowledge gap as to which were the appropriate lemon rootstocks for the Arizona industry. This trial includes rough lemon (*C. jambhiri*), a vigorous and formerly popular rootstock that is susceptible to *Phytophthora* root rot, and *C. macrophylla*, also popular, but susceptible to brown wood rot (*Coniophora eremophila*. and *Antrodia spp.*) and *Macrophylla* decline. Also included are *C. volkameriana*, a newly popular but untested rootstock, as well as 'Carrizo' citrange and 'Swingle' citrumelo as experimental rootstocks for the desert ('Carrizo' is commonly used as a rootstock for lemon in coastal California). 'Limoneira 8A Lisbon' lemon is the scion. Data collected from these trials has included tree growth, mineral nutrition, fruit quality, fruit size and total yield. Previous results from this trial have been reported in Wright and Peña (2002), Wright and Peña (2001), Wright and Peña (2000), Wright *et al.* (1999), Wright (1998), Wright (1997), Wright (1996) and Wright (1995). This trial is hereafter referred to as the 1993 Lemon Rootstock Trial.

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Another trial planted in 1995 has 'Limonero Fino 49' lemon as the scion. Fino 49 is the common fall and winter harvested lemon grown in Spain. Rootstocks in this trial include 'African' Shaddock x 'Rubidoux' trifoliate orange, 'C-35' Citrange, 'Carrizo' Citrange, 'Citremón 1449', *C. macrophylla*, *C. taiwanica*, *C. volkameriana*, 'Rough Lemon' (*C. jambhiri*), or 'Swingle' citrumelo. This trial is hereafter referred to as 1995 'Limonero Fino 49' rootstock trial.

Materials and Methods

1993 Lemon Rootstock Trial. This trial was established in March 1993 in Block 26 of the Yuma Mesa Agricultural Center, near Yuma, Arizona. The land was laser leveled and fumigated prior to planting. Trees were planted on a 10-m x 10-m spacing. Ten replicates of each of the 5 rootstocks were planted for a total of 50 trees. Experimental design is randomized complete block.

Irrigation is border flood, and normal cultural practices are used. Growth data, expressed as trunk diameter, was taken annually through 1997. Measurements were taken about 4 inches above the bud union. These locations are permanently marked with paint. Trunk diameters were taken annually in March, so as to quantify any differential growth rates that might have occurred. Leaves are collected annually in August for mineral analysis; however there have been no significant differences in leaf nutrient content. Yield data is collected during the fall and winter. Trees were ring or strip-picked as noted below. Prior to 1999-2000, about 30 lbs of fruit was sampled from each tree, and fruits were sized by hand and graded by observation. Since 1999-2000, the entire harvest from each tree has been passed through an automated electronic eye sorter (Autoline, Inc., Reedley, CA), which provides weight, color, exterior quality and size data for each fruit. Fruit packout data is reported on a percentage basis. Fruit quality data was collected at each harvest time. These data include °brix, peel thickness, percentage juice, pH, and total soluble solids to total acid ratio. There was no effect of rootstock on fruit quality (data not shown).

1995 'Limonero Fino 49' Rootstock Trial. This trial was established in June 1995 in Block 26 of the Yuma Mesa Agricultural Center, near Yuma, Arizona. The land was laser leveled and fumigated prior to planting. Trees were planted on a 10-m x 10-m spacing. There are ten complete blocks containing each of the nine rootstocks. Yields are expressed as lb. fruit per tree. Yield, packout and fruit quality data are collected as described above for the 1993 lemon trials.

All data was analyzed using SPSS 8.0 for Windows (SPSS Inc., Chicago, Illinois).

Results

1993 Lemon Rootstock Trial. Yield of trees on the five rootstocks was quite limited during the 1994-95 season. Nonetheless, significant yield differences appeared (Table 1), and trees on *C. volkameriana* rootstock had four to twelve times the yield of any other scion rootstock combination. From 1995-96 through 1997-98, both *C. macrophylla* and *C. volkameriana* produced the best yield (three to five times more than 'Carrizo' or 'Swingle'). It is notable that 1996-97 was the first year that trees on *C. macrophylla* had more yield than those trees of *C. volkameriana*, although the difference was not significant. . This trend continued in 1997-98, 1998-99 and 1999-2000, when trees on *C. macrophylla* had 22%, 16% and 35% respectively more yield than trees on *C. volkameriana*. Trees on 'Rough Lemon' produced intermediate yields, less than *C. macrophylla* and *C. volkameriana*, but more than 'Swingle' or 'Carrizo', from 1994-95 through 1999-2000. Total yields in 2000-01 were about 50 to 300 % greater than the previous year, but the general trends of the previous years remained unchanged. For 2000-01, trees on *C. macrophylla* had the greatest yield for the first harvest, about 30% more than trees on *C. volkameriana*, and about 55% greater than trees on 'Rough Lemon'.

Total yields in 2001-02 were up to 38% greater than the previous year, depending on rootstock (Table 2). This year was the first in which any rootstock produced yields of over 500 lbs. per tree. Many of the trends from previous years continued. For 2001-02, total yields of trees on *C. macrophylla* were about 18% greater than those on 'Rough

Lemon', and about 26% more than trees on *C. volkameriana*. These differences were statistically significant. This continues the trend first noted in 1996-97. All three rootstocks had about 23% of the fruit being harvested early in the first pick. Yield of trees on 'Swingle' and 'Carrizo' were much less than the other three; yields were only 23% to 27% of that of *C. macrophylla*.

Yields for 2002-03 were again higher than the previous year, ranging from a 54% increase for *C. macrophylla* to a 150% increase for 'Swingle' (Table 3). As in past years, trees on *C. macrophylla* rootstock yielded significantly more fruit than any other rootstock under test. For the first harvest (9-27-02), yields of trees on *C. macrophylla* were greater than yields on *C. volkameriana* by about 15%, and greater than yields of trees on Rough Lemon by about 30%, however these differences were not statistically significant due to the high degree of variability among the trees. 'Carrizo' yields were less than the more vigorous rootstocks, with first harvest yields ranging from 27% less than 'Rough Lemon' to 44% less than *C. macrophylla*. 'Swingle' lagged again with first harvest yields ranging from 60% less than 'Rough Lemon' to 69% less than *C. macrophylla*.

For the second harvest (12-16-02), the 950 lb. yield of trees on *C. macrophylla* surpassed all the other rootstocks tested. Yield of trees on '*C. volkameriana*' and Rough lemon were equivalent at about 800 lbs.; 15% to 20% less than the yield of *C. macrophylla*. Both 'Carrizo' and "Swingle" trees had second harvest yields less than ½ of that of *C. macrophylla*. Total yields for the 2002-03 season were heavily influenced by the 2nd harvest comprising 70 to 85% of the total yield. Only 'Carrizo' trees had significant amounts of fruit harvested early.

For ease of viewing, annual yields in lbs and field boxes per acre for trees on the five rootstocks tested can be seen graphically in Figure 1.

Packout for the September 27th 2002 harvest is shown in Figure 2. Trees on all five rootstocks had fruit that peaked on sizes 140 and 165. However, *C. macrophylla*, *C. volkameriana* and 'Rough Lemon' trees had somewhat more 95 size fruit than did the others tested, while 'Swingle' trees had fewer size 115 and more size 165 and 200 size fruit than the others. There was no effect of rootstocks on fruit grade (data not shown). There was no effect of rootstock on packout for the December 16th harvest.

1995 Limonero Fino 49' Rootstock Trial. 1998-99 through 2001-02 yields of 'Limonero Fino 49' scions on the nine rootstock cultivars are shown in Table 5. For 1998-99, yields of trees on *C. macrophylla* were 2 ½ to 8 times greater than yields on any of the other rootstocks. However, for 1999-2000, trees on *C. volkameriana* and 'Citremón 1449' rootstock were statistically the equal of *C. macrophylla*. For 2000-01 and 2001-02, *C. macrophylla* regained its prominence with yields 2 to 8 times the yield of the other rootstocks tested.

Yields for 2002-03 are shown in Table 5. All the trees had much greater yields than the previous year, irrespective of rootstock. Not surprisingly, trees on *C. macrophylla* had the greatest yield for both the first and second harvest, with all the others being intermediate, except 'African Shaddock x Rubidoux' trifoliolate' which lagged. There was no effect of rootstock upon the percent of fruit harvested early in this experiment.

Packout for the September 27th 2002 harvest is shown in Figure 3. Trees on *C. macrophylla*, *C. volkameriana* and 'Rough Lemon' trees had fruit that peaked on sizes 95, 115 and 140. All the other rootstocks led to trees that peaked on sizes 115, 140 and 165. The only significant difference in fruit size among the trees was for size 95 and 165. 'Rough Lemon' led to the greatest percentage size 95 fruit, followed by *C. macrophylla* and *C. volkameriana*, then the other rootstocks. Conversely, 'Swingle' citrumelo had the greatest quantity of fruit of size 165, followed by 'African Shaddock x Rubidoux trifoliolate', then all the others. There was no effect of rootstocks on fruit grade (data not shown). There was no effect of rootstock on packout or fruit grade for the December 16th harvest.

Discussion and Conclusions

It is still apparent that all rootstocks other than *C. macrophylla*, *C. volkameriana* and 'Rough Lemon' are unsuitable as rootstocks for lemon in Arizona in high pH soils. Reduced vigor, late fruit sizing and ultimate small fruit size are characteristics that have not yet been overcome.

Differences between *C. volkameriana* and *C. macrophylla* are becoming increasingly clear. For seven of the past eight years, yield of trees on *C. macrophylla* has equaled or surpassed the yield of trees on *C. volkameriana*. There is no clear trend as to which of these rootstocks produces earlier fruit, and overall fruit size appears to be similar. Arizona packinghouse managers report that fruit of trees on *C. macrophylla* have a smoother peel, which leads to better overall fruit quality. Growers also report that *C. volkameriana* produces more water sprouts on the trunk than does *C. macrophylla*, and that trees on *C. volkameriana* show more transient nutrient deficiencies in the winter (winter yellows), than do trees on *C. macrophylla*. Perhaps an altered fertilizer regime with more fall micronutrient application would improve the yield of *C. volkameriana* trees. It remains to be seen if yield or fruit size for *C. macrophylla* will decrease, as has occurred on older groves in Arizona.

After a slow start, 'Rough Lemon' has not had significantly different yield than *C. volkameriana* in the 1993 experiment for the past five years. 'Rough Lemon' has not typically produced as well as *C. macrophylla*, nor has it produced as much early-season fruit as the other two vigorous rootstocks tested. 'Rough Lemon' is more difficult to grow in the nursery due to its greater susceptibility to *Phytophthora* root rot, so its availability is somewhat limited unless trees are special ordered on this rootstock.

Based on the results thus far, *C. macrophylla* appears to be the superior rootstock for lemons in Arizona; although the possibility exists that it may decline sooner than 'Rough Lemon' or *C. volkameriana*. It is probably not a good idea to plant all ones acreage on only one rootstock, thus either *C. volkameriana* or 'Rough Lemon' would be a good complementary rootstock as well.

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Table 1. 1994-2001 yields of 'Limoneira 8A Lisbon' lemon trees on five different rootstocks.

Rootstock ^z	Yield per tree (lb.).						
	1994-95	1995-96	1996-97	1997-98	1998-99	1999-2000	2000-2001
'Carrizo' Citrange	0.33 b ^y	10.16 c	11.80 c	23.61 c	71.51 c	29.4 c	131.9 b
<i>C. macrophylla</i>	0.11 b	29.70 a	58.25 a	103.47 a	415.20 a	273.2 a	434.2 a
'Rough Lemon'	0.13 b	19.60 b	40.52 b	53.54 b	323.58 b	187.3 b	419.9 a
'Swingle' Citrumelo	0.15 b	11.66 c	11.13 c	37.96 bc	105.81 c	34.5 c	107.3 b
<i>C. volkameriana</i>	1.28 a	36.20 a	57.71 a	84.62 a	356.51 b	201.4 b	395.5 a

^z Values are the means of 10 trees.^y Means separation in columns by Duncan's Multiple Range Test, 5% level.

Table 2. 2001-02 yields and percentage of fruit harvested early of 'Limoneira 8A Lisbon' lemon trees on five different rootstocks.

Rootstock ^z	Yield per tree (lb.).			Pct. Fruit Harvested Early ^x
	9-27-01	11-28-01	Total Yield	
'Carrizo' Citrange	34.8 b	135.9 c	170.8 c	21.2 a
<i>C. macrophylla</i>	145.8 a	454.8 a	600.1 a	23.6 a
'Rough Lemon'	112.1 a	397.7 ab	509.8 b	22.8 a
'Swingle' Citrumelo	29.6 b	109.1 c	138.7 c	27.3 a
<i>C. volkameriana</i>	130.9 a	344.8 b	475.7 b	27.7 a

^z Values are the means of 10 trees.^y Means separation in columns by Duncan's Multiple Range Test, 5% level.^x Fruit harvested on 9/27/01 as a percentage of the total fruit harvested during the season.

Table 3. 2002-03 yields and percentage of fruit harvested early of 'Limoneira 8A Lisbon' lemon trees on five different rootstocks.

Rootstock ^z	Yield per tree (lb.).			Pct. Fruit Harvested Early ^x
	9-27-02	12-16-02	Total Yield	
'Carrizo' Citrange	98.3 b	275.8 c	374.1 c	27.8 a
<i>C. macrophylla</i>	174.9 a	775.7 a	950.6 a	19.0 ab
'Rough Lemon'	135.0 ab	652.4 b	786.4 b	17.6 b
'Swingle' Citrumelo	53.4 c	292.7 c	346.1 c	15.2 b
<i>C. volkameriana</i>	151.6 a	644.5 b	796.1 b	19.0 ab

^z Values are the means of 10 trees.^y Means separation in columns by Duncan's Multiple Range Test, 5% level.^x Fruit harvested on 9/27/02 as a percentage of the total fruit harvested during the season.

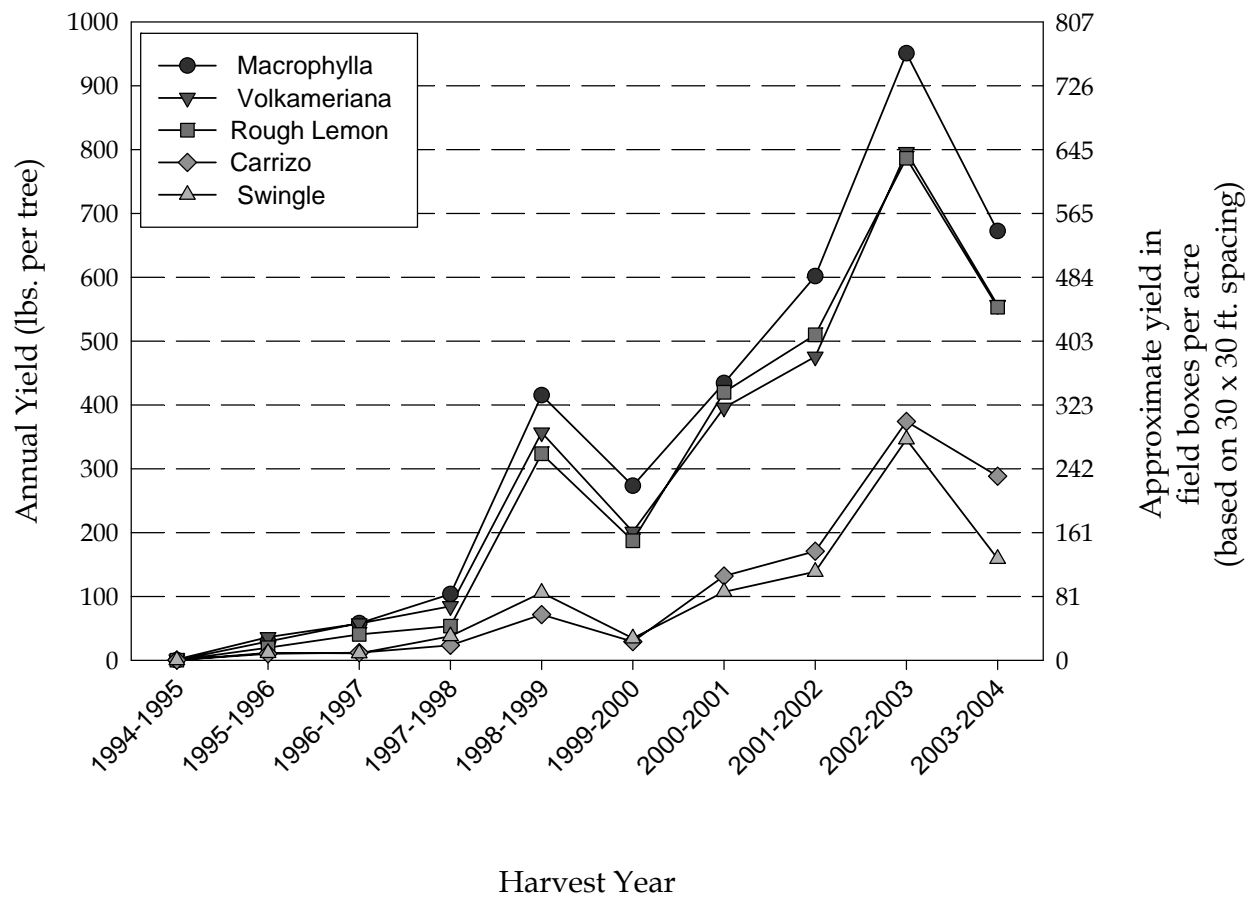
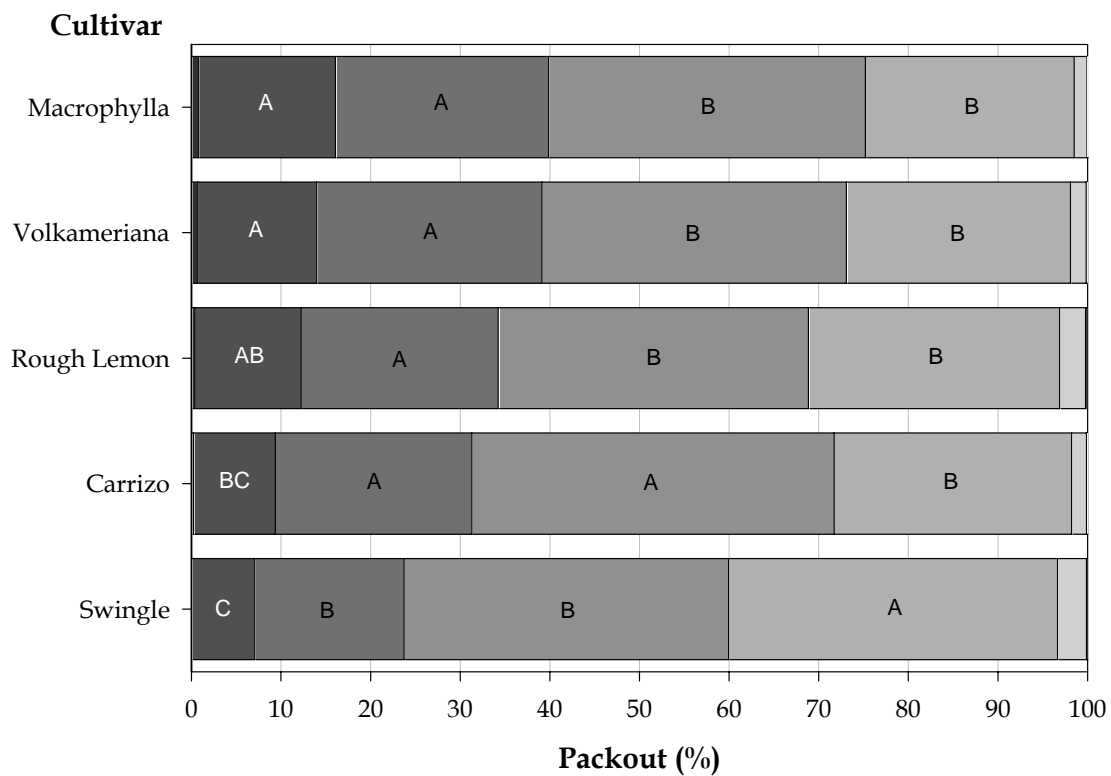


Figure 1. 'Limoneira 8A Lisbon' lemon yields on five rootstocks.

Figure 2. 2002-03 'Limoneira 8A Lisbon' Lemon on Five Rootstocks
Packout - 9/27/02 Harvest



Means separation within fruit sizes by Duncan's multiple range test, 5% level. Bars of the same shade are significantly different if the letters within them are different. Bars of different shades cannot be compared.

Table 4. Yields during 1998-2002 of 'Limonero Fino 49' lemon trees on nine different rootstocks.

Rootstock ^z	Yield per tree (lb.).			
	1998-1999	1999-2000	2000-2001	2001-2002
C. macrophylla	21.46 a	38.75 a	102.8 a	253.12 a
C. volkameriana	4.21 a	28.79 ab	50.9 b	136.63 b
'Rough Lemon'	2.04 a	3.44 c	32.2 b	95.24 bc
Carrizo Citrange	8.49 a	7.56 bc	32.0 b	70.50 c
C-35 citrange	6.26 a	12.43 bc	31.2 b	78.67 bc
Citremón 1449	5.69 a	23.74 abc	52.8 b	93.77 bc
Swingle Citrumelo	8.70 a	20.57 abc	40.8 b	40.31 c
C. taiwanica	3.51 a	2.62 c	26.4 b	35.28 c
Afr. Shaddock x Rubidoux trifoliolate.	5.65 a	4.34 bc	13.1 b	48.92 c

^z Values are the means of 9 to 15 trees.^y Means separation in columns by Duncan's Multiple Range Test, 5% level.

Table 5. Yields during 2002-2003 of 'Limonero Fino 49' lemon trees on nine different rootstocks.

Rootstock ^z	Yield per tree (lb.).		
	9-27-02	12-16-02	Total 2002-03 Yield
C. macrophylla	74.31 a	418.37 a	492.67 a
C. volkameriana	37.25 bc	229.38 b	266.64 b
'Rough Lemon'	47.20 ab	149.25 bc	196.45 bc
Carrizo Citrange	25.04 bc	119.48 bc	144.52 bc
C-35 citrange	25.21 bc	125.50 bc	150.71 bc
Citremón 1449	28.83 bc	130.64 bc	159.48 bc
Swingle Citrumelo	13.82 bc	117.80 bc	131.60 bc
C. taiwanica	20.29 bc		137.26 bc
Afr. Shaddock x Rubidoux trifoliolate.	6.36 c	97.90 c	104.28 c

^z Values are the means of 9 to 15 trees.^y Means separation in columns by Duncan's Multiple Range Test, 5% level.

Fig. 3. 2002-03 Packout of 'Limonero Fino 49' Lemon on Nine Rootstocks
9/27/02 Harvest

